International Workshop on Human Subjects

For Biomechanical Research

Minutes of Fourth Annual Meeting and Technical Session

The Fourth International Workshop on Human Subjects for Biomechanical Research was convened by Mr. Arthur E. Hirsch at 9 a.m., on October 22, 1976, at the Hyatt Regency Hotel in Dearborn, Michigan. More than 70 persons were in attendance. Mr. Hirsch's first item of business was an announcement that the mailing list was being extensively revised and that researchers interested in receiving workshop mailings should be sure their current address is part of the new mailing list. He then briefly reviewed the previous three workshops, stressing their informal nature and emphasis on open discussion. Mr. Hirsch reminded the attendees that the technical papers presented at the workshop are not to be considered published materials and are not to be referenced as such. He mentioned the use of ad-hoc committees as the method of addressing particular problems of research with cadavers. Finally, he listed four problem areas that need to be addressed by ad-hoc committees: the method of choosing cadaver materials for testing; methods for preparing cadavers; the identification of soft tissue "injuries" and then relation to AIS rating; and interpretation of test results.

Mr. Hirsch then announced that last year's discussions on affiliation have resulted in the workshop becoming affiliated with the Stapp Car Crash Conference. Each year, either the day before or the day after the Stapp Conference will be designated for the workshop. Stapp Conference letterhead will probably be used for Workshop Correspondence, and workshop arrangements will be announced with Stapp Conference announcements. Also, a Secretary to the Workshop has been designated. He is Mr. David R. Foust of the Highway Safety Research Institute at the University of Michigan. Mr. Foust has prepared minutes for three of the workshops and will continue to do so. He will also be the point of contact for workshop-related inquiries. Mr. Arthur E. Hirsch will continue to chair the workshops.

COMMITTEE REPORT

1. Ad-Hoc Committee on Guidelines for Comparison of Human and Human Analog Subjects, Dr. Daniel J. Thomas (NAMRL), Chairman.

Dr. Thomas noted that the committee had no new formal report to make at this meeting. He briefly reviewed the six guidelines presented in the two reports the committee has prepared in previous years. He invited any researchers who wish to have copies of those reports to contact him directly at NAMRL, Detachment 1, Box 29407, Michoud Station, New Orleans, Louisiana 70189. Dr. Thomas asked if other researchers had successfully used the guidelines and had produced data that were useful in analytical models. Discussion centered on the T1 anatomical coordinate system and the fact that it is available only through radiological examination rather than by palpation. The need was cited for an externally-available coordinate system for human volunteers. Dr. Thomas commented that a rigid coordinate system is needed that can describe the dynamic input to the head and neck, and that they have not been able to devise a better one than the system located at T1. He also noted that only one set of 3-D X-rays is needed for a human volunteer subject and that those are roughly equivalent in exposure to a single chest X-ray.

There were three sessions of prepared discussion in conjunction with this committee report. Dr. H.M. Reynolds, HSRI, and Dr. Clyde Snow, FAA/CAMI, discussed preparations for a new study of pelvic anthropometry which was begun recently. Dr. Reynolds described the experimental design for the project. Using HEW data, he has been able to closely match population height/weight, size statistics for 5th, 50th and 95th percentile females and males (total of 6 cells) to a sample of prepared skeletal material. The sample is being taken from the Hamann-Todd collection of approximately 3000 skeletons at the Cleveland Museum of Natural History. This collection is unique in that a large group of anthropometric measures were obtained from each cadaver prior to skeletal preparation. The study sample will consist of 300 (150 male, 150 female) complete pelvises from the collection together with the anthropometry for those specimens. Dr. Snow then reviewed the pelvic measurement techniques. Of interest to the workshop is the fact that 120 landmarks have been specified. Twelve pairs of measurements will be taken of the entire pelvis, and the remainder from one-half of the pelvis (bilateral symmetry is assumed) and the whole sacrum. These landmarks will be located in three-dimensional space relative to an external coordinate system, using a computerized three-dimensional digitizer. An additional feature of the study is the use of various-sized hemispheres which fit into the acetabulum and can be used to locate an anatomical H-point (at the center of the fitted hemisphere).

Further prepared discussion was presented by Dr. A.J. Padgaonkar, Wayne State University. He reviewed his experience, generally successfully, in using the committee guidelines to establish landmarks and locate accelerometer mounts relative to body coordinate systems. He also described a series of recommended landmarks for locating mounts on the upper leg, lower leg, upper arm and lower arm. He noted potential problems with parallax in X-ray studies and the importance of proper positioning of the cadaver prior to obtaining X-rays. Finally he described a mathematical method of establishing correct landmarks from X-ray films. This method measures angles between landmarks and corrects for alignment errors to produce a new direction cosine. He was able to define coordinate systems accurately using this method.

Dr. Thomas noted an alternate way of establishing landmarks using the 3-D X-ray technique and a three-point array. This allows the angular relationships to be calculated later and greatly simplifies subject positioning. He also encouraged Dr. Padgaonkar to publish his methodology and the accompanying error analysis. Other comments were made regarding the use of a point on the position-dependent radius as a landmark rather than one on the ulna.

Mr. Hirsch then requested Dr. Thomas' opinion on the future of the guidelines committee. Dr. Thomas feels that, since the committee is ad-hoc and informal, it should remain in existence. It will continue to deal with concepts and problem areas. He recommended that techniques and methologies based on the concepts be developed and published.

2. <u>Ad-Hoc Committee on Detailed Injury Scaling, Dr. John W. Melvin, HSRI and Dr. Claude H. Tarriere, Peugeot-Renault, Co-Chairmen</u>

Dr. Melvin began the committee report by noting that the problem of "injury" scaling of cadavers is a diffuse one, of too large a scale for group committee action. He recommended that the body be divided into regions. A single volunteer familiar with testing problems of that region would then develop a preferred scaling method for that region and obtain comments from other researchers. The objective would be to have the proposed scaling method available for discussion at the next workshop. Dr. Melvin cited four areas of concern to the committee-cadaver selection, preparation for test, autopsy procedure and "injury" rating. He emphasized the need for comparability among techniques used by different research teams, especially in the latter two areas. Finally he suggested dividing the body into the following regions for purposes of developing rating systems: Head, spine, thorax, abdomen, and pelvis/lower extremities. He further suggested that a volunteer be sought from both the U.S. and the European research groups for each region.

There was some discussion at this point regarding the advisability of segmenting the body and handling the different regions independently especially for the selection and preparation topics. The argument was that selection and preparation tend to be whole-body activities, while autopsy and rating are often related to tests of separate body regions. This point of view was adopted by the workshop.

Mr. Hirsch then noted that the output of a cadaver test rating should relate directly to the AIS information being gathered by in-depth accident investigation projects. He felt the committee should coordinate with the AAAM and others who define injury assessment. Dr. John D. States, University of Rochester, offered to provide the necessary link, since he both attends the workshops and is on the AAAM Committee responsible for the Abbreviated Injury Scale. Volunteers for establishing the protocols for injury rating were then solicited.

Dr. A.K. Ommaya, National Institues of Health, discussed the potential value of EMI scanning as a selection or pre-autopsy technique. EMI scanning produces cross-sectional computerized tomographs with significant detail. Its use is currently restricted due to limited availability of scanners and because the cost of a whole body scan approaches $1000. Under certain conditions, however, EMI scanning could provide valuable information.

Dr. Melvin then asked if a separate committee was needed to study specific preparation techniques such as pressurization. The workshop consensus was that no action is needed before next year, but that researchers should give special attention to preparation problems involving pressurization.

The committee report concluded with prepared discussion by Dr. John D. States, University of Rochester. He reviewed the injury scaling system developed by AAAM, noting that the Abbreviated Injury Scale (AIS) is intended to be a scale of injuries to live patients, and that a comprehensive scale has also been developed. Dr. D.F. Huelke, University of Michigan, is the contact for problems encountered in using the scales. He noted that an international group (the Neurotraumatology Committee) is now proposing methods for scaling concussion and coma. This will be a clinically-oriented head injury scale and may not be appropriate for research with cadavers, but Dr. States will be receiving the committee's recommendations for review. Dr. States also recommended two standards for autopsy - one for research purposes and one for accident investigation team use. The second would be aimed at the "average" pathologist who is not normally involved in crash injury research. He recommended that the workshop scaling committee maintain some contact with the Accident Investigation Division of NHTSA.

TECHNICAL SESSION

With the completion of the committee reports and prepared discussions, the Technical Session of t e workshop was begun. Fifteen brief, informal presentations were given, relating to the general areas of cadaver utilization and characterization and test instrumentation techniques. This section of the minutes includes a brief description of the presentations. More detail for many of the presentations may be found in the papers which follow these minutes.

Prior to beginning the Technical Session, Mr. Hirsch introduced Dr. Wiseley, Chief of Forensic Medicine in the Los Angeles County Medical Examiner's Office. Dr. Wiseley was representing Dr. T.T. Noguchi, the Los Angeles County Medical Examiner.

Validity Studies

1. Comparison of the Vivo and Cadaver Brain Injuries, Dr. W. Alter, Armed Forces Radiological Research Institute. Dr. Alter described a series of whiplash-injury comparison tests in which angular accelerations of the head were produced in anesthetized and fresh cadaver cynomolgus (Macaca fascicularis) monkeys. The head was fixed in dental stone for the tests; a small "window" was built into the helmet for observation purposes. Accelerations of the head were measured by accelerometers placed at the midbrain and at the C1-C2 and T1-T2 levels of the spine. These locations were thought to represent primarily angular, a combination of angular and translational, and primarily translational motions, respectively. Accelerations were applied at sub-concussive, concussive, and superconcussive levels such that the center of rotation would be at the midbrain. For each concussive level, rotations of 30°, 45°, and 60° were induced. Cadaver monkeys were tested with pressurization of the brain vascular system. Dr. Alter described the response of anesthetized monkeys (superconcussive level, 60° rotation) as arrythmia, aprea, bradycardia, and hypotension at the midbrain. Although cadaver monkeys were tested within a few days of

death, no hemorrhage was demonstrated in the brain tissue, and the gyri were flattened due to disruption of the blood-brain barrier and resulting edema of brain tissue. Dr. Alter observed that the entire vascular system may not be filled with the pressurization method.

In response to questions, Dr. Alter mentioned that only saline was used to pressurize the brain, and that pressurization began immediately prior to the test. Dr. Alter did not draw any conclusions at this time regarding the comparability between tests with living and cadaver specimens.

2. Shaker-produced Brain Motions in Cadaver and Living Monkeys, Dr. W. Alter, Armed Forces Radiological Research Institute. Dr. Alter's second paper was an interim report on the use of vibrating shaker tables to produce brain motions which are then studied using high-speed X-rays. This study has four objectives: (1) effects of constant-frequency vibrations, (2) effects of resonant constant-frequency vibrations, (3) differences between brain motions of living and fresh cadaver monkeys, and (4) experimental data to validate the finite-element head model under development by Dr. C.C. Ward at the Naval Civil Engineering Laboratory. The technique employs a form of high-speed X-ray which allows frame rates up to 1000 per second, but for a limited number of frames. The current exposure is 500 frames per second for a maximum of 50 frames. The monkeys are prepared by implanting a row of radiopaque pellets in the brain, .75 cm off the midline and one cm below the skull surface. A matching row of pellets is attached to the skull surface. The animal is in the supine position, with the head in a rigid helmet on the shaker table an angular acceleration is imparted. At low frequencies, skull excursion is one cm; at high frequencies (30 Hz), excursion is 2mm. Dr. Alter showed a film of high-speed X-ray which illustrated a slight out-of-phase relative motion between the two rows of pellets. However, since lead pellets (density 11) were used, it is possible that the relative motion was due to density differences between the pellets and the brain. Dr. Alter reported that leaded glass pellets (isodense) of 1.05 density will be used in future tests. They have noted no heart rate or blood pressure changes in live animals at constant vibration up to 35 Hz. Cadaver animals are tested 24 hours after euthanasia, using the same specimen as was tested live. This project is still in its early stages and Dr. Alter mentioned five tasks yet to be accomplished: (1) establish if there are relative motions using leaded glass spheres, (2) increment pellet location from skull surface to center of rotation to document extent of relative motions, (3) compare motions in different parts of the brain, (4) vary the time lapse between euthanasia and cadaver testing, and (5) emplace the pellets in a cadaver to simulate the method required for human cadaver testing. They are not currently planning to test the response to various modes of vibration, except perhaps at the center of rotation.

3. Classification of Cranio-Encephalic Lesions, Dr. C.H. Tarriere, Association of Peugeot-Renault. Dr. Tarriere briefly described the results of a recent lateral-impact injury study, noting that more injuries occur to the head than to any other body region. He proposed that a large, common effort be directed

at using cadavers to reconstruct real head impact injuries. He cited several difficulties in analysis of head injuries, specifically: (1) no correlation has been established between observable skull injuries and associated brain lesions; (2) secondary lesions are not identified; (3) severe lesions are not precisely described; and (4) brain lesions are only indirectly classified. He emphasized the need for a classification system that will (1) distinguish between different injuries, and (2) correlate injuries with levels of impact severity, separating the sequelae of trauma for both survivable injuries (with and without skull fracture) and fatalities (with autopsies designed to identify primary and secondary lesions and describe fractures in detail). Dr. Tarriere finished his remarks by citing three examples to demonstrate how analysis procedures could provide desirable data.

4. Brain Pressurization - Carbon Particles as a Means for Detecting Vascular Injury, Dr. R.W. Smith, University of California at San Diego. Medical science is aware that there are substantial changes in the brain vasculature from minutes to hours after death, but that the blood vessels remain patent and do not "leak." Dr. Smith is now trying to assess what changes may occur to blood vessels within 24 to 48 hours after if the brain is immediately refrigerated. Dr. Smith then reported on a technique being used at UCSD to use India ink particles in pressurized cadaver brain vasculature as an indicator of brain lesions. Just prior to testing, the vasculature of the brain is pressurized to 150 mm of mercury with a perfusate of saline and India ink, via the carotid arteries. The cerebrospinal fluid spaces are also pressurized to 70 mm of water. Post-test autopsy has revealed a viable ability to completely perfuse the vasculature, since the anatomy of the Circle of Willis often creates "shunts" which prevent total perfusion. When adequately perfused, however, the perfusate is found in all vessels. These experiments have also demonstrated a sensitive vascular injury model, since ink particles can indicate lesions ranging from slight disruption to major contusion. Dr. Smith was asked to compare India ink particle size with blood constituents; he noted that they are several microns larger than red blood cells.

5. Brain Pressurization - Controlled Pressurization Techniques at HSRI, G.S. Nusholtz, HSRI. Mr. Nusholtz described the techniques formerly and currently in use at HSRI to perfuse the brain vasculature. The current method requires only one incision in the carotid artery and minimizes fluid leaks. A balloon catheter is inserted into the ascending aorta to plug it and allow maintenance of vascular pressure. Perfusate is introduced into the carotid artery at a constant pressure of 100mm of mercury. An in-line pressure transducer measures the pressure so it can be maintained accurately. The system uses a continual fluid flow to perfuse during a test, and it is portable enough to use reliably in a sled test. At the time of test, the in-line pressure transducer shows good correlation between the impact force pulse and the resulting vascular pressure pulse. Post-test, HSRI is noting perfusate generally through the white matter, often in a mottled pattern, even though it may not be visible on the surface of the cortex.

In answer to questions, Mr. Nusholtz noted that the brain is usually not perfused completely, that between one-fifth and one gallon of perfusate is used per test (not all of which goes to the head) and that fluid sometimes leaks past the aortic balloon, but without reducing the constant pressure. Cadavers are tested between 12 hours and 2 weeks after death. The effects of these delays on the results of a test cannot be assessed at this time. Dr. Ommaya observed that the mottled appearance of the cortex might be due to multiple small ruptures, as this condition is also seen in patients with hypertension.

6. Balloon Inflation Tests in Living and Cadaver Monkey Brains, Dr. A.K. Ommaya, National Institutes of Health. Dr. Ommaya discussed recent work* which is better defining pressure-volume effects on brain tissue response. It is now known that, if leakage is created in the brain, the spread of edema can be predicted and that this spread changes grossly with changes in blood pressure. Leakage can occur in brain tissue, from cerebrospinal fluid spaces, and from the vascular system, with the least amount of leakage occurring in brain tissue. Recent experimental evidence with monkeys shows that when a rapid increase in intracranial pressure is created by inflating a balloon in the subdural space, systemic pressure of the vascular system will increase rapidly until brain death occurs (the brain maintains function until intracranial pressures reach blood pressure). If, however, intracranial pressure is increased slowly, the blood pressure maintains a "flat response." It is also possible to infiltrate more fluid into the brain if it is done slowly. Dr. Ommaya has concluded from these experiments that the brain can exhibit variations in "stiffness" during response, depending on the degree and method of pressurization. With cadaver monkeys, Dr. Ommaya has noted that a long-dead brain, when pressurized, shows a relatively flat linear response to volume increases. However, if the brain had been subjected to high pressure before death, it maintained a "memory" for up to six hours after death and repeated a "high-pressure" type response regardless of the rate of volumetric increase. Dr. Ommaya feels that brain compliance is a critical factor in impact testing with cadavers, and that a test needs to be devised to determined the optimum "rigidity" state of the brain for each cadaver. A question was asked regarding response of the brain to impulsive increases in pressure. Dr. Ommaya indicated that impulsive loading is being attempted, but that difficulties in inflating the balloon have to date prevented loading in less than 100 msec. They currently measure pulses between 0.1 and one second.

7. Comparison of Crash Simulator - Produced Injuries in Living and Cadaver Baboons, Captain Kilian, Air Force Aeromedical Research Laboratory. Captain Kilian described some preliminary results from a group of accelerator sled tests being performed with heavily sedated and cadaver baboons. The baboons are restrained at the pelvis and torso with a 3-point restraint. Test series are being run at sled accelerations of 40, 50, and 70 g. Cadaver animals were kept at 70°F for 24 hours before the test, and the joints were manipulated prior to testing. Cadavers are not pressurized in either the airway or the vascular system. Captain Kilian outlined several comparisons

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* "Volume Pressue Curves and Pial Vascular Pressure Gradients in the Rhesus Monkey." Nakatani, S. and Ommaya, A.K. Intracranial Pressure II. International Symposium on Intracranial Pressure, Lundberg, Ponten and Brock (Eds) 2d, Lund, 1974. Berlin, Heidelberg, New York, Springer-Verlag, 1975, pp. 89-96.

between live and cadaver animals as a result of the 50- and 70-g tests. Overall, cadaver "injury" data tended to be grouped lower than those of live animals, with fairly large differences at the 70 g level. No head or neck injuries were observed from either test group, but thoracic fractures were found in live animals. HIC was calculated for each test, but since no skull impact occurred, there is no significant difference between the various g- levels. Some differences in head acceleration waveforms were observed, and these attributed to the cadaver having a less stiff neck. A questioner noted that acceleration waveforms measured at the top of the head could vary with the animal's position relative to the torso restraint system and asked what steps were being taken to assure a uniform restraint position from test to test. Captain Kilian indicated that the restraint system was not positioned precisely and that attachment points were not varied, so that results are compared only between animals of similar size or from one test to another of the same individual. In response to other questions, Captain Kilian said that an apparently stiffer chest in the cadavers explained different chest kinematics, and that the typical injuries after high-g tests were fractures of the sternum and separated muscles in the abdomen.

INSTRUMENTATION

8. Introductory Remarks, Dr. R. Eppinger, NHTSA. Dr. Eppinger introduced the instrumentation portion of the Technical Session by citing two prime reasons why it is important at this time to define three dimensional motion in the dynamic environment, especially for the head-neck system. First, the time history of translation and rotation of the head and neck will be important in future criteria. Data are needed now so they can be used later for comparison. Secondly, data are need to define a more representative biokinematic test dummy and to describe relative motions between various anatomical structures. Data are needed now so that motions from today's tests can be reassessed to demonstrate how well new devices mimic experimental specimens. Dr. Eppinger also mentioned that he is trying to write a contract specification to govern the inertial measurement system for the head. The specification is rather loosely defined at this time.

9. Review of Head Rotational Measurement Systems, A.K. Johnson, NHTSA. The nine accelerometer system to measure accelerations under dynamic conditions is coming into wide-spread usage. Mr. Johnson presented material which points out some of the systematic errors that can occur with the use of this system, and briefly discussed an alternative approach. The theory of using nine accelerometers to describe three dimensional motion demonstrates that angular accelerations can be calculated using only linear acceleration inputs in the equations of motion. Mr. Johnson showed that systematic (as opposed to random) errors can introduce unwanted angular acceleration terms into the equations and lead to false solutions. He discussed the errors of cross-axis sensitivity, accelerometer mismatch, and accelerometer misalignment as the chief potential problems.

Rate gyros measure angular velocity directly, but they are currently heavy for cadaver testing applications, very expensive, and limited in responsiveness. Mr. Johnson recommended further study of rate gyro applications. A paper, which was co-authored by A.S. Hu, New Mexico State University, illustrates the mathematical theory behind the presentation. It is included with these proceedings. Mr. Johnson was asked about the availability of rate gyros. Two were mentioned- the Hamilton-Standard Superjet (one axis 5000°/sec., 1 in., dia., 1.5 in. long, 1.5 ounces); and one manufactured by Honeywell (two axis, approximately 1000°/sec, 25 ounces). An instrumentation manufacturer commented that most cross-talk in linear systems comes from misalignment, since the two errors are related. The presentation closed with the comments that NHTSA is not now recommending a change to rate gyros, but that it would be worthwhile to investigate them further. Dr. Eppinger noted that NHTSA has let a contract for construction of a rotational acceleration testing device designed to test and calibrate nine accelerometer systems.

10. Second Progress Report on Mouth-Contained Acceleration Transmitter, E.F. Konigsberg returned to this year's workshop to report the progress in development of a miniaturized nine accelerometer measurement system and telemetry transmitter which is entirely contained in a boxer's mouthpiece. The unit has been built and it works, and vibration testing was to begin the first week of November. Several of the mouthpieces were available for inspection. The mouthpiece unit contains nine accelerometers (housed in a cube 0.56 inches on a side) and the necessary electronics to telemeter nine acceleration channels plus three channels of calculated angular acceleration. Output is ±125 g over .5-500 Hz. A paper describing the design and specifications is included in the proceedings. Mr. Konigsberg received questions regarding cost and availability. He indicated that the units will be produced commerically after the development program is complete. The cost is not yet established, but will probably be in the $1500 range (probably less expensive if the accelerometers are housed in a large cube, since calibration would be much less costly).

11. Utilization of the Nine Accelerometer System with Anthropomorphic Dummies, Dr. S.C. Sinka, Wayne State University. Dr. Sinka conducted a series of planar motion sled tests at 10, 20, and 30 mph, using a anthropomorphic dummy. He compared the acceleration of the head CG as calculated from a nine accelerometer system and as measured by the triaxial system at the dummy head CG. He reported a good match at all three velocities (maximum difference was 6 percent at 30 mph), even with large amounts of head rotation. The results of these tests were just published in the Journal of Biomechanics, Volume 9, No. 10.

12. Location in Space of a Nine Accelerometer System on Cadavers - Dr. C. Hasler, Battelle Institute. Battelle uses an indirect method to locate the position in space of an accelerometer system when used in a cadaver test. The mounting plate for the accelerometer system is locked and cemented to the skull

structure. The head is then placed in a sterotaxic device and the location of the mount relative to skull landmarks is measured. Three dimples on the plate are used to precisely position the accelerometers, so that knowledge of the mount location automatically locates the accelerometer axes.

13. Nine accelerometer System Experience at HSRI, Dr. J.W. Melvin, HSRI. For head motion analysis in cadaver tests, HSRI has adopted the use of three triaxial accelerometers, each mounted separately on the skull. X-ray photogrammetric analysis is used to measure the accelerometer locations relative to the test specimen. HSRI has conducted a test with an embalmed cadaver, in which the output of triaxial accelerometers placed at the base of the skull is compared the results of a skull-mounted nine axis system. The nine-accelerometer system accurately predicted the accelerations measured by the triaxial system.

At this point Captain Kilian, AMRL, mentioned that he is having some problems in mounting the nine-accelerometer system to the skull of live subjects. He also noted that, when the mounting is secure, the system works very well.

Comparability Between Cadavers

At the Third Annual Workshop, considerable attention had been devoted to establishing a simple test that each researcher could perform on every cadaver tested, so that the effects of cadaver condition on test results might be more easily assessed. A rib fracture test reported by Granick and Stein in the Journal of Biomechanics was recommended and several research groups agree to perform the test and report to this year's workshop.

14. Rib Testing Techniques at the University of Heidelberg, Dr. D. Kallieris, University of Heidelberg, Germany. Dr. Kallieris has tested 128 segments from 44 males and 20 females who died of natural causes. Each sample was 10 cm in length. Sixth-rib segments were loaded to the concave side, seventh-rib segments to the convex side, although the Granick and Stein method of loading was not used. Results indicated that the absolute strength of the male sixth-rib segments increased to age 40, then decreased. Increasing strength was found in males only to age 30 with the seventh-rib segments. For females, both sixth and seventh ribs decreased in absolute strength from age 20 (the youngest sample). However, when normalized for fracture load per unit area, there were almost no male-female differences. Dr. Kallieris defines rib fracture as the maximum load achieved. He noted little difference in results of tests with two ribs from the same person. M.J. Walsh, Calspan, commented that his results show same-individual differences even after normalizing for cross-sectional area.

15. Experience with the alternative to the Granick and Stein Rib Test, Mr. M.J. Walsh, Calspan. Mr. Walsh reported that he has been using the Granick and Stein test since 1975, but that he now proposes a different comparability test. The Granick and Stein technique applies to rib testing a method which is designed for linear anisotropic homogeneous materials. In actual practice, it is difficult to measure the needed cross-sectional area of the bone, the rib must be thoroughly cleaned before the area is measured, and the necessary beam length is difficult to obtain. Also, the method must be used after the dynamic test has already been run. Mr. Walsh proposed a test using the radius, which can be performed pre-test as a screening method. The technique involves a parabolic index reported by Epker and Frost in the Journal of Gerontology, Vol. 19, October 1964. The index compares cortical bone area to marrow area for a thin cross-section of the radius. This index is appropriate to cadaver testing since it assesses the degree of osteoporosis. It is also accepted by orthopedists. Calspan has used this technique and has successfully matched the norms applied by Epker and Frost.

Following this presentation, there was a discussion period dealing with rib testing. Dr. Hasler of Battelle noted that the ultraviolet illumination designated by Granick and Stein was too intense and that they now cut cross-sections of ribs before measuring area. Dr. Melvin, HSRI, described some problems with the rib section crushing in some cases and deflecting to a V-shape without breaking in others. HSRI used a larger-radius loading pad to reduce this problem. Mr. Walsh, Calspan, reported similar problems but did not change the loading radius to maintain consistency with other Granick and Stein test results. Dr. Melvin also suggested that researchers use both the Granick and Stein and Epker and Frost tests during the next year and report findings at the Fifth Workshop. This suggestion was accepted by many of the researchers present.

At this point, the Technical Session was completed. Mr. Hirsch announced that the Fifth International Workshop would be held on Tuesday, October 18, 1977, in New Orleans, Louisiana, the day immediately preceding the 21st Stapp Car Crash Conference. The workshop was concluded at 5:00 p.m.

David R. Foust, HSRI
Secretary